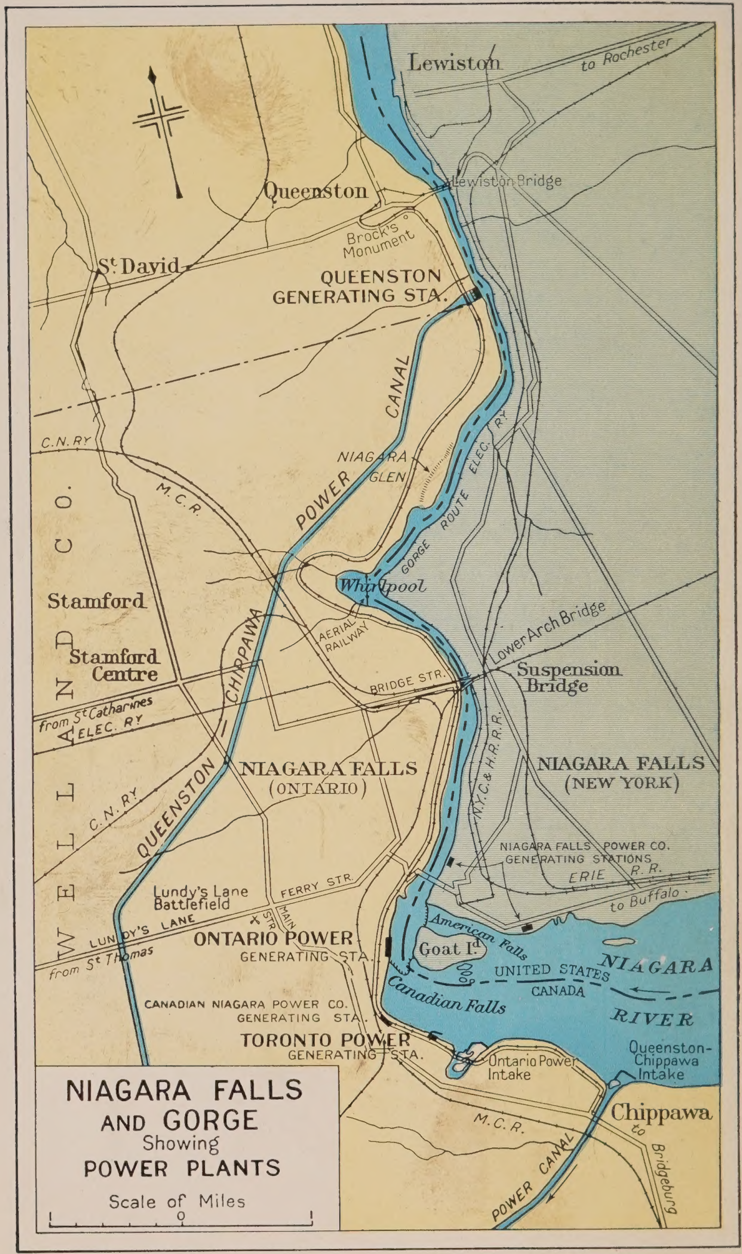
Ontario, Hydro-electric Power Commission

Power development on the Niagara River.

NIAGARA POWER

HYDRO-ELECTRIC POWER COMMISSION
OF ONTARIO



Lewiston
to Rochester
Queenston
Lewiston Bridge
Brock's Monument
St. David
QUEENSTON GENERATING STA.
CANAL
C.N. RY
NIAGARA GLEN
POWER
M.C.R.
ELEC. RY
GORGE ROUTE
Whirlpool
Stamford
Stamford Centre
CHIPPAWA
AERIAL RAILWAY
Lower Arch Bridge
Suspension Bridge
BRIDGE STR.
from St Catharines ELEC. RY
WELLAND CO.
NIAGARA FALLS (ONTARIO)
NIAGARA FALLS (NEW YORK)
N.Y.C. & H.R.R.R.
C.N. RY
QUEENSTON
NIAGARA FALLS POWER CO. GENERATING STATIONS
ERIE R. R.
to Buffalo
Lundy's Lane Battlefield
FERRY STR.
LUNDY'S LANE
STR.
MAIN
ONTARIO POWER GENERATING STA.
American Falls
Goat Id.
UNITED STATES
CANADA
NIAGARA
RIVER
from St Thomas
Canadian Falls
CANADIAN NIAGARA POWER CO. GENERATING STA.
TORONTO POWER GENERATING STA.
Ontario Power Intake
Queenston-Chippawa Intake
Chippawa
M.C.R.
to Bridgeburg
POWER CANAL
NIAGARA FALLS AND GORGE
Showing
POWER PLANTS
Scale of Miles
0

Power Development

on the

Niagara River

Power Plants

of the

Hydro-Electric Power Commission of Ontario

CONTENTS

AMERICAN FALLS

The Niagara River

THE Niagara river joining lake Erie to lake Ontario has a total length of 35 miles. The difference in elevation between lake Erie, at elevation 572 feet above sea level, and lake Ontario, 246 feet, is 326 feet.

For the first 20 miles from lake Erie to the head of the upper rapids the Niagara is a broad stream varying from about one-half mile to one mile in width. The deepest channel above the rapids has a depth of 30 feet, and the fall of the river in the 20-mile stretch is only 10 feet. The drop in the upper rapids is about 55 feet in a stretch of one mile.

The Canadian or Horseshoe falls are 162 feet high and have a crest length of 2,600 feet with a depth of water of 12 feet at the centre. The American falls are 167 feet high and 1,000 feet wide, with an average depth of about 1½ feet. The International Boundary passes over the Horseshoe falls not far from the shore of Goat island, and it is estimated that close to 95 per cent of the water flows over the Canadian falls.

Below the falls for a distance of nearly two miles the river has a depth of about 190 feet; it is 40 feet deep in the Whirlpool rapids, 125 feet in the Whirlpool itself, and about 100 feet for the remainder of the distance as far as Queenston. The width of the stream below the falls is more than 1,000 feet, but at the narrowest point in the Niagara glen the river is confined to a channel about 330 feet wide. In the lower rapids a drop of nearly 100 feet occurs in the water level over a distance of seven miles.

CANADIAN FALLS

Facts re Niagara River and Falls

Lake Erie to Lake Ontario—Length 35 miles, fall 326 feet.

Lake Erie to Head of Upper rapids—Length 20 miles, fall 10 feet, width ½ to 1 mile, depth 30 feet maximum.

Head of Upper Rapids to Crest of Falls—Length about one mile, fall 55 feet, maximum depth at crest about 12 feet.

Canadian or Horseshoe Falls—Crest length 2,600 feet, height 162 feet.

American Falls—Crest length 1,000 feet, height 167 feet.

Horseshoe Falls to Whirlpool Rapids—Length 2 miles, depth about 190 feet, fall 1 foot.

Whirlpool Rapids—Length 1 mile, depth about 40 feet, fall 52 feet.

Whirlpool—Depth about 125 feet.

Whirlpool Rapids to Lake Ontario—Length 11 miles, depth 100 feet, fall 47 feet.

Average Discharge of River—210,000 cubic feet per second.

Watershed Area—260,000 square miles.

Gorge—Length 7 miles, height of banks near Queenston 300 feet.

RAPIDS OF NIAGARA RIVER GORGE—LOOKING DOWNSTREAM

The Power of Niagara

THE potential power of a river depends upon its flow and its descent. If the flow is uniform and the descent concentrated in falls or steep rapids the value of its developable water-power is greatly increased. Nowhere else in the world are large uniform flow and concentrated descent combined as they are on the Niagara river. The Niagara river, therefore, is the greatest water-power stream in the world, and furthermore its value is immensely enhanced by its proximity to densely-populated areas both in the United States and in the Dominion of Canada.

The Great Lakes constitute the greatest fresh-water system in the world. Lakes Superior, Huron, Michigan and Erie, the four largest, are above the Niagara river and act as balancing reservoirs for the run-off from a total drainage area of 260,000 square miles. The average flow of the Niagara river is about 210,000 cubic feet of water per second.

The power expended by the stream in its descent of 326 feet from lake Erie to lake Ontario amounts to nearly 8,000,000 horsepower. The theoretical electrical power obtainable by utilizing the whole flow with the maximum developable head of about 300 feet at 90 per cent efficiency would be about 6,400,000 horsepower. Similarly, the power that could be developed under a head of 300 feet with a diversion of 120,000 cubic feet per second—rather more than half the flow—would be about 3,670,000 horsepower.

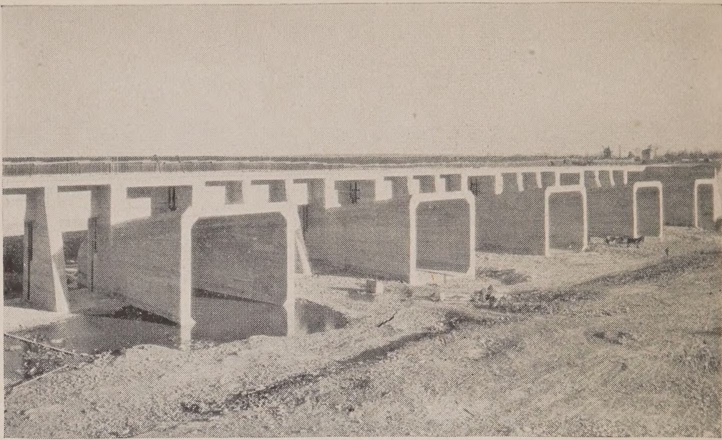
THE CANADIAN FALLS IN WINTER

The Power of Niagara

The present development of power on the Niagara river is, under the Boundary Waters Treaty of 1909-10 between Great Britain and the United States, limited to that developable from flows of water "not exceeding in the aggregate a daily diversion at the rate of" 56,000 cubic feet per second. The primary reason for entering into this Treaty was the preservation of the scenic beauty of the falls. The benefits derivable from the use of boundary waters belong equally to both countries, but for physical reasons it was regarded as preferable to divert 20,000 cubic feet per second on the United States side of the river and 36,000 cubic feet per second on the Canadian side. The difference in permissible diversion on the Canadian side of the river was offset by the exportation to the United States of electrical energy developed in power plants on the Canadian side of the Niagara river.

Canadian Power Developments on the Niagara River

ASIDE from the plant of the Canadian Niagara Power Company—a corporation controlled by the Niagara Falls Power Company of the State of New York—and a small installation belonging to the International Railway Company, all of the power generated on the Canadian side of the river is now produced under public ownership and control.



QUEENSTON-CHIPPAWA POWER DEVELOPMENT
Intake structure, now submerged — note size by men and team

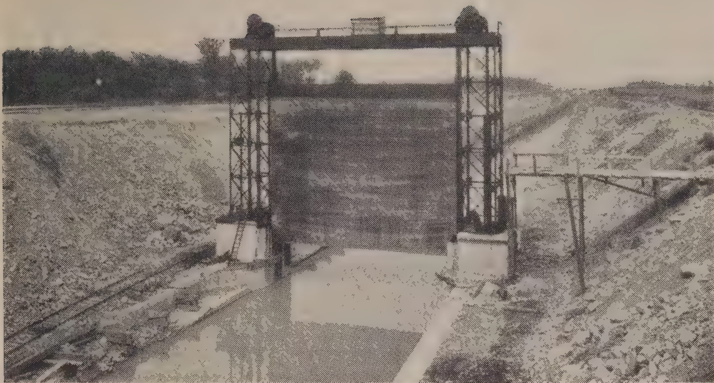
Canadian Power Developments on the Niagara River

The three plants known as the Queenston-Chippawa, the Ontario Power and the Toronto Power developments—are owned collectively by municipalities of Ontario which have combined to provide for their citizens ample supplies of electrical energy *at cost.* These plants are operated by the Hydro-Electric Power Commission of Ontario, which is the central administrative body. Further reference is made to this Ontario undertaking on pages 23 to 29. Space in this pamphlet permits only a brief description of the plants. Some supplementary information is given in tabular form.

Queenston-Chippawa Power Development

THE Queenston-Chippawa development, the largest power plant on the Niagara river and for years the largest hydro-electric power plant in the world, is still in the front rank of the world's greatest and most efficient hydro-electric plants. It commenced to deliver power in January, 1922, and was completed by the installation of a tenth unit in 1930. Diverting water from above the rapids of the upper river and returning the water to the river below the rapids in the lower Niagara gorge, this plant has the distinction of being the only one to make use of the maximum head between lakes Erie and Ontario capable of economic utilization.

The general scheme of development comprises an intake structure in the Niagara river at Chippawa; the deepening and enlarging of the Welland river with a reversal of its flow for 4 miles; the construction of a canal 8¾ miles long from Montrose on the Welland



QUEENSTON-CHIPPAWA POWER DEVELOPMENT
Control gate on power canal — 48 feet clear span

river to the forebay and screen house, which are situated on the cliff above the power house, where the banks on the lower Niagara river rise more than 300 feet above the water level, about one mile south of the village of Queenston.

Intake Structure

IN order to divert from the Niagara river above the rapids and falls large quantities of water, especially during the winter when the river is heavily charged with ice, special structures are necessary. In the case of the Queenston-Chippawa development the structures include an entrance channel with lock gates for navigation, a bulkhead section, and the intake proper. This consists of a concrete barrier or boom with fifteen openings each 18 feet wide, together with six submerged openings which form part of a supplementary intake designed as an ultimate protection against ice difficulties. The intake works are situated at Chippawa, two miles above the Horseshoe falls. The greater part of the intake works is submerged, but an idea of the size of this mammoth structure may be obtained from the accompanying illustration.

The Power Canal

THE power canal has a total length of 12¾ miles and may be said to consist of three sections, the Welland river section, the earth section and the rock section. The first section is 4 miles long and consists of the straightened and deepened river channel. The second section is excavated in earth and is a channel with sloping sides, the top width

being 307 feet, and the bottom width 185 feet. The bottom grade of the earth section meets the rock about one and one-half miles from the Welland river. The third section is in rock with an earth overburden and has a length of 7¼ miles. The rock cut is rectangular, with a width of 48 feet and a maximum depth of rock cut of 85 feet. The maximum depth of the canal cutting through both earth and rock is 143 feet below the ground surface. There are five bends in the canal with curvatures ranging from 27 to 51 degrees. At one place near the Whirlpool the canal is carried on a fill across a ravine. In this section its shape is changed to a trapezoidal form with a bottom width of 10 feet and side slopes of 1 on 1½. The transitional points from rectangular to trapezoidal form are interesting examples of concrete construction. To increase its carrying capacity by reducing friction the rock section of the canal below the water level is lined with concrete.

Near the entrance to the rock section is placed an electrically-operated roller sluice control gate of 48 feet clear span. The gate is supported on steel towers and weighs about 100 tons. When fully raised it permits the passage of a tug beneath.

Forebay and Screen House

THE canal terminates in a triangular basin called a forebay, across the base of which, and approximately parallel to the face of the cliff, is built the screen house. This structure forms the entrance to the penstocks or pipes supplying water to the turbines, and houses the racks and upper control for the penstocks. The entrance to each penstock is a modified bell-mouth divided into three openings, each 12 feet 8 inches wide and 28 feet high, which converge to one opening 16 feet in diameter at the entrance to the penstocks. Racks are provided in each of these openings for the screening of debris from the water before it enters the turbines. Provision is also made in each opening for the installation of portable headgates when it is desired to unwater the penstocks. At the south end of the screen house is the Administration building and reception hall.

Penstocks

FROM the screen house the water is conveyed to the lower part of the power house through great steel pipes, known as penstocks, 14 to 16 feet in diameter, which lead directly to the hydraulic turbines. A large plunger valve of the Johnson type is installed at the lower end of each penstock and is arranged to close automatically in case of an emergency. These valves can also be operated by remote control from strategic points in the power house.

Power canal at Lundy's Lane curve, prior to admission of water.
Floor of canal at this point is 140 feet below ground level

Queenston-Chippawa Power Development

Visitors to the power house descend in an electric elevator through a 22-ft.-diameter shaft in solid rock from the reception hall in screen house to a tunnel 200 feet long, which leads to the seventh floor of the power house about two-thirds of the way down the cliff. From this level, elevators in the power house itself connect with the nine floors of the building. Consult sketch on pages 16-17.

POWER CANAL TRAVERSING THE NIAGARA PENINSULA—ONTARIO

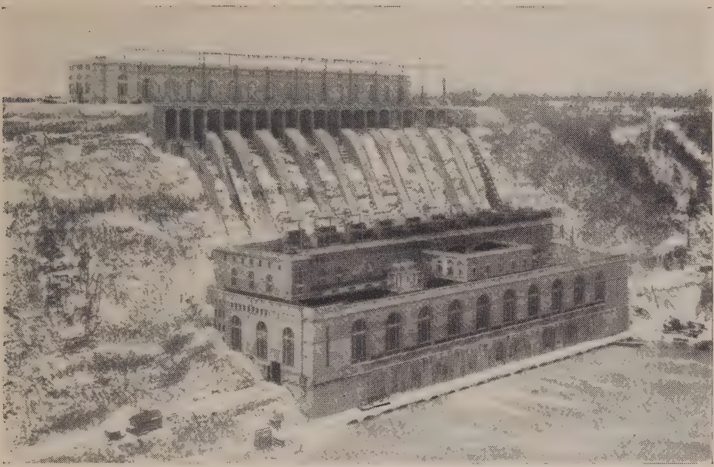
Queenston-Chippawa Power Development

Power House

THE power house itself is a building of immense proportions. If it were placed in front of the American Fall it would nearly hide it. Its completed length to house the ten main units and two service units which it now contains exceeds 590 feet. Its substructure is of massive concrete carried down to rock foundation, and the superstructure, consisting of a structural steel framework with reinforced concrete floors and roof, rises about 180 feet above the rock foundation, or more than half way up the cliff.

Each main unit consists of a turbine, generator and exciter. The turbines are technically described as of the vertical, single-runner type. Their capacities vary from 55,000 to 58,000 horsepower. At maximum load they operate under a water head of about 294 feet and their speed is 187½ revolutions per minute. The normal operating capacity of the development is about 525,000 horsepower.

Each of the huge generators is assembled directly over its turbine and is enclosed in a concrete compartment below the main floor. Their rotating parts are directly coupled to the turbine shafts. Above the main floor are visible only the upper bearing brackets, the main thrust bearings and the exciters. The thrust bearings—which are self-oiling—support the entire weight of the rotating parts of turbine, generator and exciter, a total of 340 tons per unit. On this same floor, and to one side of each main unit, stands the governor,



THE GREAT POWER HOUSE AT QUEENSTON

which is driven by a belt from the turbine shaft. The function of the governor is to maintain constant speed on the main units by altering the openings of the gates which admit water to the runner of the turbine. Access to the lower portions of the units is obtained by stairways leading to various galleries and passage-ways. On number two floor, the visitor may see, below and to one side of the gallery, the great 14-foot plunger valves which are used to close off the water from the turbine for inspection or repairs, and also in cases of emergency. On the other side of the gallery are the apparatus and mechanism which, under control of the governor, regulate the flow of water to the turbine under varying conditions of load.

Three-phase alternating current is generated at 12,000 volts and at a frequency of 25 cycles per second. The current from each generator passes through its own switches and transformers. The oil switches are placed at strategic points in each circuit so that in case of trouble they will automatically open and thus localize the trouble and maintain power supply to the greatest possible extent. The transformers are used to "step-up" the voltage from 12,000 volts to 110,000 volts for transmission. The aluminum conductors carrying current at this voltage pass out through specially designed structures on the roof of the station, up the cliff to steel towers erected upon the edge of the escarpment, and thence to the transmission lines radiating throughout southern Ontario. Some of the power is sent as far west as Windsor and Sarnia, about 240 miles away.

Operating The Plants

IN so brief a description of these great developments, only the outstanding features can be touched upon, but a few words may profitably be devoted to the care and attention that is required in operation. Each plant has its own control room where, separated from the noise of the great power-producing units, engineers and operators, aided by automatic signalling and control devices of extreme ingenuity and delicacy unceasingly watch the performance of the equipment in their charge. Power developments such as these, though guarded with the utmost care in design and construction, are, nevertheless, susceptible to a variety of troubles, among the causes of which the forces of nature, through the agency of lightning, wind and sleet, play a prominent part. Lightning creates enormous electrical stresses in the insulating materials of transmission lines and sometimes, in spite of all precautions to by-pass it, enters the generating stations. No harm results unless the insulation fails, but if it fails within the station the damage resulting may be very serious and far-reaching. Lightning storms are the cause of more trouble than any other single factor, and perhaps wind with sleet is a close second, imposing as it does severe mechanical overloads in transmission lines and occasionally bringing them down. Few people, who in such cases suffer temporary inconvenience due to suspension of electrical service, stop for a moment to think about the efforts which are being made to restore their service, or if they did would have any idea of the hardships endured by linemen and others in their unceasing efforts to correct the trouble. Not infrequently these men work under the most trying conditions for even 36 and 48 hours without rest, stopping only for necessary food. Often all this is going on without any interruption to service at all, the apparatus or lines affected being replaced temporarily by alternative routes which constitute a second line of defense.

A service enemy almost equally dreaded is ice, which occurs in the water supply to the turbines in various forms such as hard blocks, frazil, anchor ice and slush. The anchor ice frequently carries with it rocks of considerable size. Each plant has problems peculiar to itself and every year ice is fought with all available means, such expedients as mechanical drags, large forces of men with various implements, and the explosive power of dynamite being employed.

In the power houses themselves the operators must constantly be on guard against incipient mechanical and electrical troubles; failure of lubricating systems, cooling systems, relaying and signalling

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

Interior of the great generating station at Queenston constructed for the co-operating municipalities of Ontario by the Hydro-Electric Power Commission. View shows ten main generating units with two service units in foreground. Only the upper frame and exciter of the main units are above floor level. The generator proper and the turbine are encased in concrete.

SCREEN HOUSE, ADMINISTRATION BUILDING AND RECEPTION HALL

systems and many other things. In many cases they have only a few seconds to recognize trouble, to decide upon the preventive measures, and to make the only move which may save thousands of dollars and safeguard the service. Only by unremitting vigilance can excellence in service be maintained.

A post of equal responsibility, though perhaps of less interest to the observer, is occupied by the load supervisor whose important duty it is to correlate the output of all three generating stations and apportion the water available under treaty terms for power development so as to produce from it the maximum possible amount of energy. He also controls the distribution of power in response to the varying demands from the different sections of the vast transmission networks of the Commission's Niagara system.

It is difficult to convey an appreciation of the enormous power concentrated within the four walls of the greatest hydro-electric power station in the world. A simple illustration must suffice. One only of these great units will supply the average needs of an industrial city of 100,000 people for electrical energy, to turn the wheels of its factories, to drive its street cars and elevators, to light its streets and business houses, to pump its water, and to supply a superior electrical service to the homes of its citizens.

Facts re Queenston-Chippawa Development

Intake Works: Situated at mouth of Welland river at Chippawa. Depth of water 35 feet.

Canal: Welland River Section—Length 4 miles. Top width 307 feet. Bottom width 185 feet. Earth Section—Length 1½ miles. Top width 307 feet. Bottom width 185 feet. Rock Section—Length 7¼ miles. Width 48 feet. Total length 12¾ miles. Depth of water in canal 30 to 38 feet.

Deepest earth cut 70 feet. Deepest rock cut 85 feet. Deepest combined earth and rock cut—143 feet.

Earth excavated 29,250,000 cubic yards; rock excavated 4,350,000 cubic yards. Concrete placed 340,000 cubic yards.

Length of construction railway 83 track miles.

Forebay: Area 6 acres. Depth of water 28 feet.

Screen House: Length 550 feet. Number of openings 31. Size of openings leading to main penstocks—three to each penstock—12 feet 8 in. by 28 feet.

Elevator to Power House: Depth of shaft 212 feet. Length of tunnel 200 feet.

Steel Penstocks: Number—10 main penstocks and 1 service penstock. Length 383 feet. Diameter of main penstocks 16 feet.

Head of Water: Normal gross head 315 feet. Normal net operating head, full load conditions, 294 feet.

Generating Station: Length 590 feet. Width 135 feet. Height above rock foundation 180 feet. Number of floors 9. Constructed of reinforced concrete with steel framework.

Main Turbines: Number—10. Type: Francis, vertical, single runner. Horsepower of individual units, 55,000 to 58,000 horsepower. Total *rated* capacity 560,000 horsepower. Speed 187½ revolutions per minute.

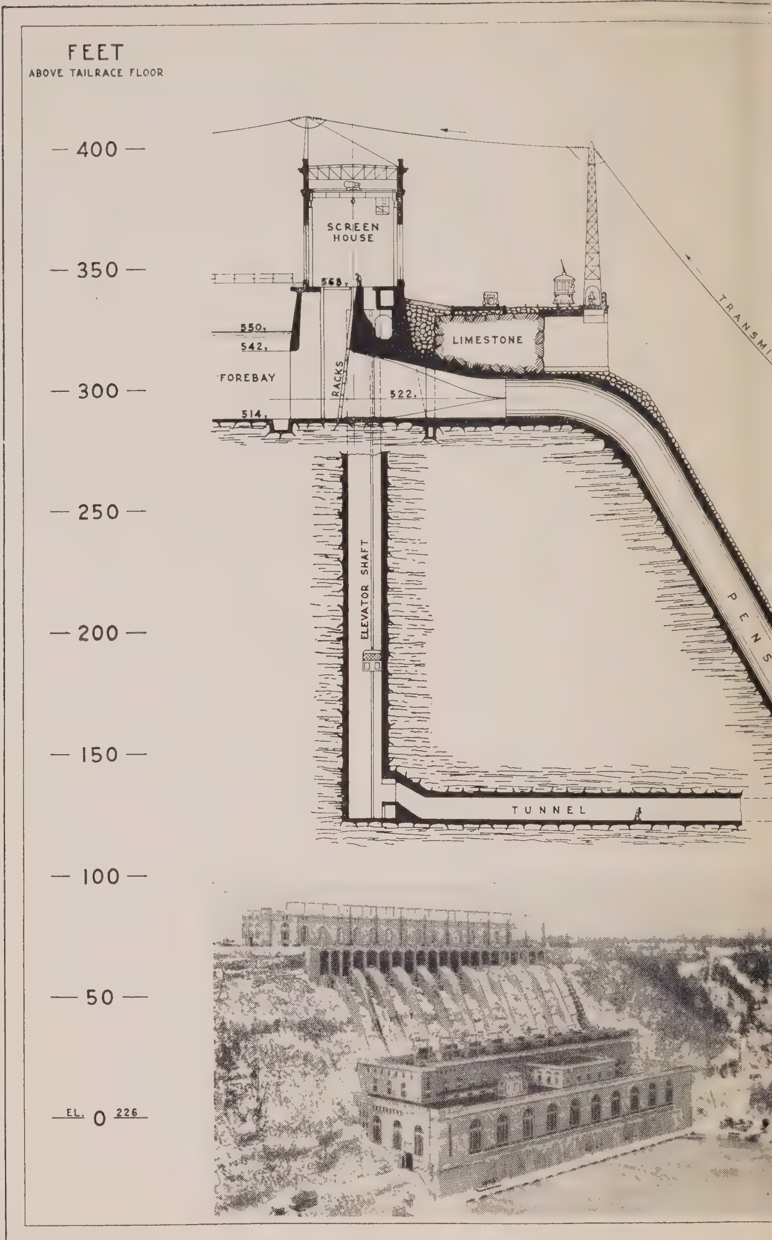
Main Generators: Number—10. Type: Alternating current, three-phase. Voltage: 12,000. Frequency 25 cycles. Capacity of units, 45,000 to 55,000 kv-a. Total *rated* capacity 497,000 kv-a.

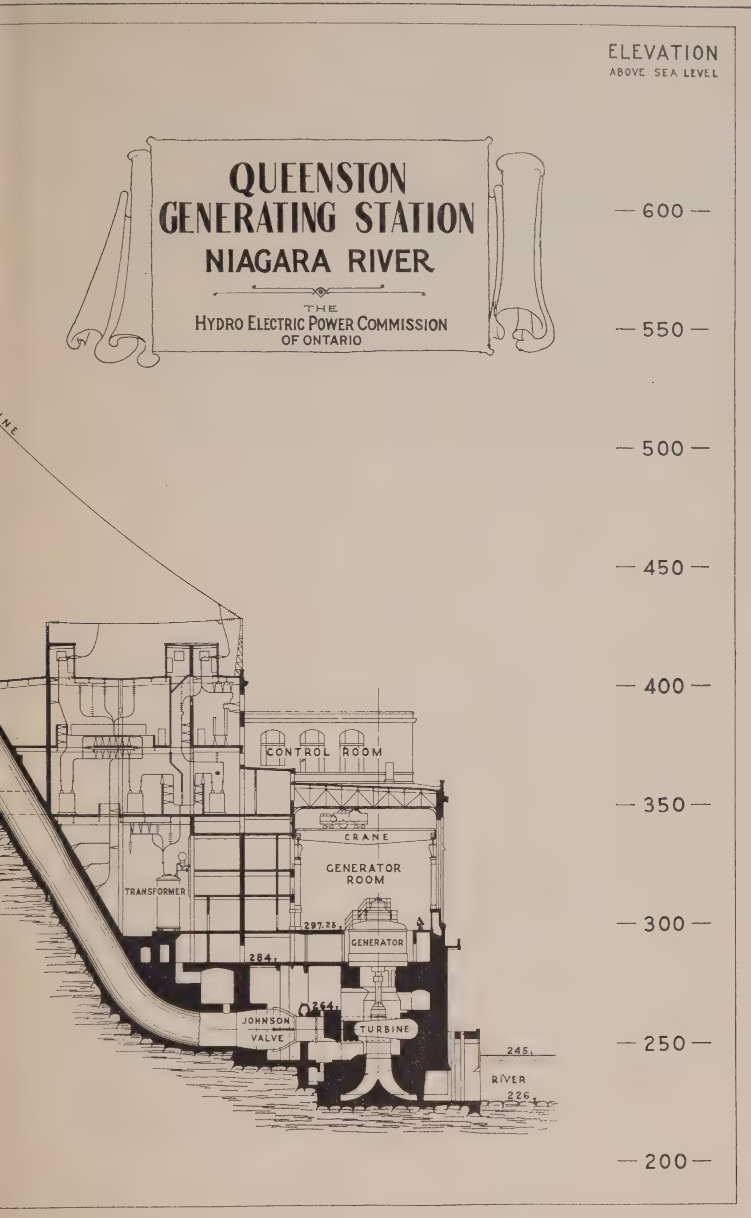
Weights: Weight of heaviest part of main units 315 tons. Weight of rotating parts of turbine and generator combined 340 tons. Total weight of each main unit 1,044 tons.

Service Units: Number—2. Capacity of each 2,200 kv-a.

Transformers: Number—3 per main unit. Capacity, five banks, 15,000 kv-a., five banks, 18,330 kv-a., each transformer; 12,000/63,400 volts, star-connected for 110,000-volt operation. Weight, 100 tons each.

Oil Circuit-Breakers: Number: 2-12,000-volt and 3-135,000-volt breakers per main unit. Interrupting capacity 1,500,000 kv-a.


FEET
ABOVE TAILRACE FLOOR
400
350
300
250
200
150
100
50
EL. 0 226
SCREEN HOUSE
568
550
542
FOREBAY
RACKS
522
514
LIMESTONE
ELEVATOR SHAFT
TUNNEL

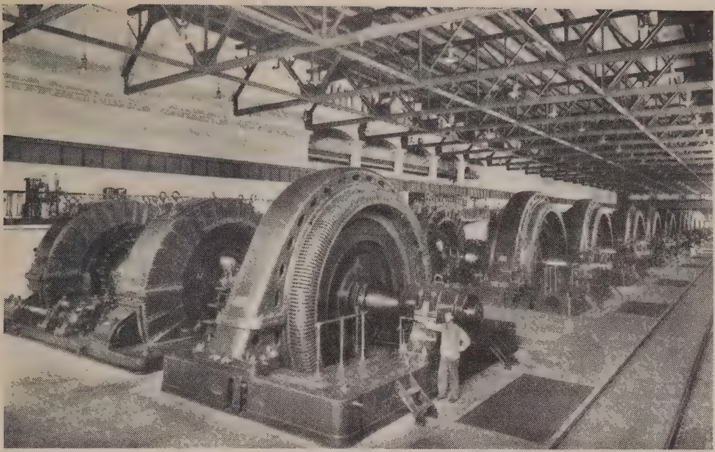

QUEENSTON GENERATING STATION
NIAGARA RIVER
THE
HYDRO ELECTRIC POWER COMMISSION
OF ONTARIO
ELEVATION
ABOVE SEA LEVEL
600
550
500
450
400
350
300
250
200
CONTROL ROOM
CRANE
GENERATOR ROOM
TRANSFORMER
297.25
GENERATOR
284
264
JOHNSON
VALVE
TURBINE
245
RIVER
226

ONTARIO POWER GENERATING STATION
Designed to harmonize with surroundings by blending with cliff behind

Ontario Power Development

THIS development is the largest and most efficient of the power plants on the Canadian side of the river in the immediate vicinity of the Falls. It utilizes, however, a head of only 180 feet as compared with the 300 feet developed at the Queenston-Chippawa plant. It was originally constructed by a privately-owned company. Construction started in 1902, the first three units were in operation in 1905, and the capacity was gradually increased until, in 1914, fourteen units served by two pipe lines were installed, the total rated capacity being 185,000 horsepower. In 1917, the municipalities of Ontario, through their Hydro-Electric Power Commission, purchased the capital stock of the Ontario Power Company and its subsidiary the Ontario Transmission Company, acquiring thereby the Company's water rights and assuming its contracts and obligations. To meet urgent demands for power during the War, a third pipe line and two additional units were installed and the operating capacity was increased.

Water for the operation of this plant is taken from the river at a point about a mile above the crest of the Horseshoe falls, and conveyed 6,500 feet through conduits laid underground, then through steel penstocks placed in tunnels through solid rock, to the generating station at the base of the cliff opposite Goat island, where it passes through the horizontal turbines and thence beneath the power house to the river.



ONTARIO POWER GENERATING STATION
Interior showing horizontal twin turbines and alternators

Ontario Power Development

Access to the power house is obtained by means of an elevator and tunnel from an entrance building in Queen Victoria Park. From the same entrance another tunnel and elevator give access to the distributing station situated high up on the plateau behind the Park.

In this power house not only the generators but the turbines also, having horizontal shafts, are mostly above floor level and the assemblage of power-producing machinery in some respects is more impressive even than in the Queenston-Chippawa plant. There are 15 main turbo-generator units now operating in the plant.

The turbines are of the horizontal double-runner, central-discharge type and range in capacity from 11,700 to 20,000 horsepower. The output of the generators is transmitted by underground cables to the transformer and distributing station.

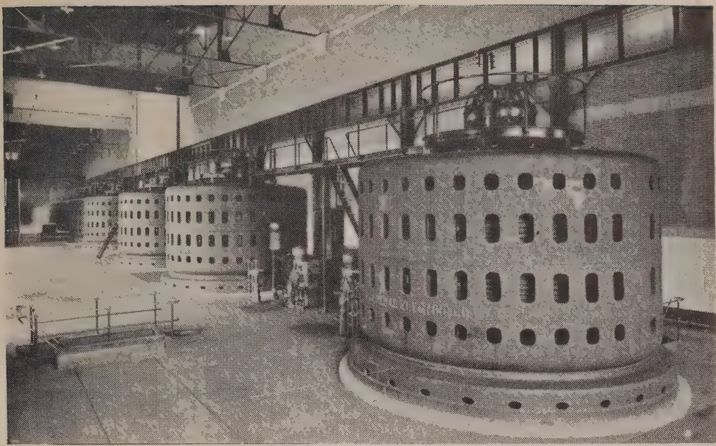
The various buildings and other structures of the Ontario Power development are prominent features of the surroundings of Niagara Falls and occupy portions of the park reservation on the Canadian side. They have therefore been designed to harmonize with their surroundings and the Company co-operated with the Queen Victoria Niagara Falls Park Commission in furthering the scheme of scenic improvement. It has been estimated that the Company spent more than a million dollars for the sole purpose of preserving the artistic values of the environs of Niagara Falls.

TORONTO POWER GENERATING STATION
A splendid view of the upper rapids is obtained from terrace at left

Toronto Power Development

THIS development, like the "Ontario Power" development, was constructed by a private company in the early years of the present century. Its design permits the utilization of only a portion of the power obtainable in the immediate vicinity of the Falls; the average effective head developed being 137 feet, or less than half that utilized by the Queenston-Chippawa development. A noteworthy feature of this plant is that the generating plant is situated close to the intake; another that the development was made on land reclaimed from the river bed itself. The ground upon which this plant now stands was formerly covered with water 8 to 24 feet deep. On the land reclaimed the wheel pit was excavated. It is 416 feet long, 22 feet wide and 156 feet deep from the power-house floor. It is brick-lined; the turbines, which are fed by vertical steel-plate penstocks, are placed near the bottom and the generators at the top; each generator is coupled to its turbine by a long vertical steel shaft supported by several flying arches spanning the wheel-pit.

Water collected from the river by the wing dam passes through submerged arches into the intake and thence down steel penstocks, 10 feet 6 inches in diameter, to the turbines. After giving up its energy the water passes from the turbines, alternately, into two tunnels paralleling the wheel pit on either side and converging at



TORONTO POWER GENERATING STATION
Interior showing vertical shaft generators

Toronto Power Development

the lower end of the power house into the main tailrace tunnel which has its outlet under the river behind the Horseshoe falls, about 12 feet above the present normal level of the lower river.

Below the power-house floor in isolated concrete compartments are placed the oil switches, power busbars, etc.; the current is transmitted from the power house to a transformer station placed on the crest of the hill overlooking the Falls.

The design of the power house building in its classical proportions is striking and impressive. Built of Indiana limestone, it is 462 feet long and 91 feet wide. A magnificent view of the rapids is obtained from the loggia at the northern end.

When the Ontario Power development and the Toronto Power development were constructed, they embodied the latest advances in the art of hydro-electric development. Homage must be paid to the men of vision and enterprise who planned these great plants at a time when the market for electrical energy was only in the earlier stages of the phenomenal growth which it has since manifested. Homage also should be paid to the engineers who designed and constructed these plants at a time when the art itself had many unsolved problems to face.

Facts re "Ontario Power" Development

Intake: Just above rapids. Outer forebay—area 8 acres, depth of water 15 feet. Inner forebay—area 2 acres, depth of water 20 to 30 feet.

Screen House: Length 320 feet.

Water Conduits: Number 3. Length about 6,500 feet each. Diameters—Two at 18 feet and one at 13 feet, 6 inches. Material—One steel, one concrete, one wood stave with concrete envelope.

Steel Penstocks: Number—16. Lengths 225 to 317 feet. Diameters—Fourteen at 9 feet and two at 10 feet 6 inches. Thickness, 3/8 inch at top, 7/8 inch at bottom.

Head of Water: Normal gross head 202 feet. Normal net operating head, full load conditions, 180 feet.

Generating Station: Length 778 feet. Width 80 feet. Height from power house floor 46 feet 6 inches, from rock 72 feet. Constructed of reinforced concrete with steel framework.

Main Turbines. Number—15. Type—Reaction, with horizontal twin runners. Horsepower—11,700 to 20,000 each. Total *rated* capacity 195,700 horsepower. Speed—187½ revolutions per minute.

Main Generators: Number—15. Type—Alternating current, three-phase. Voltage 12,000. Frequency 25 cycles. Capacity of units 7,500 to 15,000 kv-a. Total *rated* capacity 134,000 kv-a.

Facts re "Toronto Power" Development

Intake: In rapids above Falls. Depth of water in forebay 27 feet.

Wheelpit: Length 416 feet. Width inside lining 22 feet. Depth below rock level 126 feet. Excavated in limestone and shale and lined with brick.

Penstocks: Number—11. Length 127 feet. Diameter 10 feet, 6 inches.

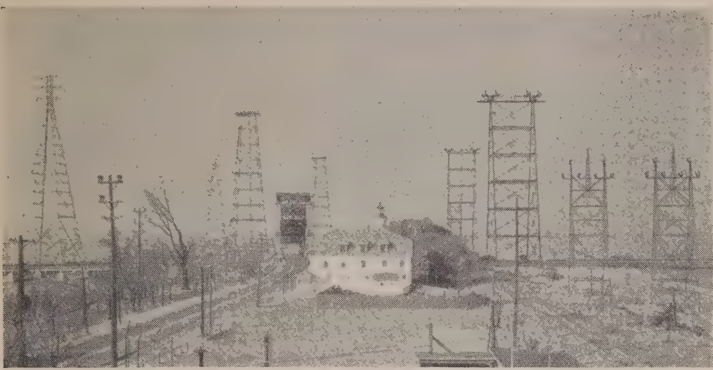
Head of Water: Net operating head, light load to full load, 152 feet to 135 feet.

Tailrace Tunnel: Length about 2,690 feet. Width 23 feet 6 inches. Height 26 feet 1½ inches.

Generating Station: Length 462 feet. Width 91 feet. Height 80 feet. Constructed of cut stone, with steel framework.

Main Turbines: Number—11. Type: Francis, vertical, double-runner. Horsepower 13,000 to 15,500 each. Total *rated* capacity 160,500 horsepower. Speed 250 revolutions per minute.

Main Generators: Number—11. Type: Alternating current, three-phase. Voltage 12,000. Frequency 25 cycles. Capacity of units 8,000 to 10,000 kv-a. Total *rated* capacity 102,000 kv-a.



TRANSMISSION LINES CROSSING ENTRANCE TO HAMILTON BAY—ONTARIO

Ontario's Unique Electrical Service

THE electrical undertaking administered for Ontario municipalities by the Hydro-Electric Power Commission of Ontario is a co-operative municipal-ownership enterprise, province-wide in its field, operating through the agency of independent commission control and administration and free from so-called political influence. Broadly, the Commission is entrusted with the duty of supplying the electrical needs of the citizens of Ontario municipalities at the lowest possible cost consistent with sound economics. The Commission has now been actually supplying electrical energy for a period of nearly twenty-five years. During this period the costs of electricity to the consumer have been substantially reduced and the finances of the enterprise have been established on an increasingly secure foundation.

Fundamentals that have been insisted upon from the beginning are, that business principles must strictly be followed in all phases of operation and of finance, that there will be no so-called political interference, and that government participation in the undertaking will be limited to that degree of supervision of general policies necessary for the protection of the guarantees of the Province in connection with the enterprise.

This public-ownership enterprise, administered with fidelity and designed to meet the circumstances existent in the Province of Ontario, is eminently satisfactory to the citizens of the Province and on their behalf renders a service that is unsurpassed in any other comparable territory. The service given by the Commission is popularly referred to as "Hydro service" and throughout the Province the organization is known as "the Hydro"; terms which apply both to the central organization which distributes power

wholesale to the municipalities and to the local municipal authorities which distribute electricity to the individual consumers.

For nearly twenty years, the head of the Hydro-Electric Power Commission was the late Sir Adam Beck. Upon the creation of the Commission in 1906, he was appointed Chairman, a position he held until his death in August, 1925. The outstanding success of this great public-ownership undertaking is, in large measure, due to his forceful leadership, constructive ability and zeal, and administrative capacity.

The first distribution of electrical energy by the Commission was in the year 1910 and by the end of that year it was supplying power to about ten urban municipalities. On behalf of the co-operating municipalities, the Hydro-Electric Power Commission of Ontario now supplies electrical service to about 750 municipalities of which 390 are urban municipalities—including 27 cities and 95 towns—and 360 are townships. The small initial load of less than 1,000 horsepower increased year by year until the Commission's load has reached 1,250,000 horsepower. Provision has been made for power to take care of an aggregate load of about 1,800,000 horsepower.

At the outset of its operations, the Hydro-Electric Power Commission proceeded to construct a network of transmission lines in order to link up with Niagara Falls the municipalities which first came into partnership. These transmission networks have extended rapidly and at times their growth has been accentuated by the inclusion and consolidation of existing smaller networks following the purchase of private companies formerly operating within these areas. The main transmission lines of the Commission now total about 5,100 miles, and include more than 1,100 miles of 110,000-volt line; 190 miles of 132,000-volt line, and 600 miles of 220,000-volt line.

A feature which, particularly in recent years, has been of great economic benefit to the Province as a whole, is the extension of electrical service to agricultural areas through the formation of rural power districts. In connection with these rural power districts which are operated on behalf of the townships directly by the Commission, about 9,000 miles of primary distributing lines have been constructed, and many villages, hamlets and individual farmers are receiving the benefits of "Hydro" electrical service.

Power for the operation of the various systems is obtained from thirty-eight electrical power developments operated by the Commission, supplemented in certain cases by power from privately-owned developments. The Niagara system is by far the largest and its power is obtained from the three large power developments on the Niagara river, already described; from a development at De Cew Falls; from one at Chats Falls on the Ottawa river, and from privately-owned plants in the province of Quebec.

RURAL ELECTRICAL SERVICE IN ONTARIO

Electric milking
Rural scene
Water supply

Motor driven cream separator
Power lines on rural highway
Motor driving feed chopper, etc.

Financial and Administrative Features

THE hydro-electrical undertaking of the co-operating municipalities of Ontario, embracing all the operations from the provision of the power down to its final delivery to the ultimate consumer, involves two distinct phases of operations. The FIRST is the provision of the electrical power—either by generation or purchase—and its transformation, transmission and delivery in *wholesale* quantities to individual municipal utilities, to large industrial consumers, and to rural power districts. This phase of the operations is performed by the Hydro-Electric Power Commission of Ontario as trustee for the municipalities acting collectively in groups or "systems."

The SECOND phase of operations is the *retail* distribution of electrical energy to consumers within the limits of the areas served by the various municipal utilities and rural power districts. In the case of cities, towns and villages, the operations are performed by municipal utility commissions under the general supervision of the Hydro-Electric Power Commission of Ontario. In the case of rural power districts the Hydro-Electric Power Commission not only provides the power at wholesale, but attends to all physical and financial operations connected with the distribution of this power at retail to the customers within the rural power districts.

The basic principle governing the financial operations of the undertaking is that service be given by the Commission to the municipalities, and by the municipalities to the ultimate consumer, *at cost.* The ultimate source of all revenue to meet costs—whether for the larger operations of the Hydro-Electric Power Commission or for the smaller local operations of the municipalities—is, of course, the consumer. Out of the total revenue collected by each municipal utility from its consumers, only an amount sufficient to pay the wholesale cost of power supplied by the Commission is remitted to the Commission; the balance is retained to pay for the expenses incurred by the local utility in distributing the electrical energy to its consumers.

With respect to the charges by the Commission to the municipalities, these vary with the amounts of power used, the distances from the sources of supply and other factors. The entire capital cost of the various power developments and transmission systems is annually allocated to the connected municipalities and other wholesale power consumers, according to the relative use made of the lines and equipment. Each municipality assumes responsibility for that portion of property employed in providing and transmitting power for its use, together with such expenses—including the cost of purchased power if any—as are incidental to the provision and delivery of its wholesale power. The entire annual expenses,—including appropriations

for reserves,—incurred by the Commission in the supply of power at wholesale are thus paid out of revenues collected in respect of such power, through the medium of power bills rendered by the Commission. The municipalities are billed at an estimated interim rate each month, and credit or debit adjustment is made at the end of the year, when the Commission's books are closed and the actual cost payable by each municipality for power received has been determined.

With respect to the charges by the municipality to the ultimate consumer, the control of the retail rates is, under the Power Commission Act, vested in the Commission. The rates to the consumers of each class are designed, on the basis of detailed cost records, to secure from each class a revenue equal to the cost of providing service to it, plus such a margin of surplus over estimated costs as shall ensure financial stability. The *form* of the rate schedules for each class of service is designed to ensure, as far as is practicable, that each consumer is charged with the actual cost of the service he receives.

Included in the municipality's remittance to the Commission for the wholesale cost of power—besides such direct expenses as those for operation and maintenance of plant, for administration, and for interest on capital—are sums required to build up reserves for sinking fund, renewals, obsolescence and contingencies. Similarly, the expenses incurred by the local utilities in the retail distribution of power include,—besides operating, maintenance and administration expenses,—interest on the capital investment, sinking fund or principal payments on debentures, and depreciation charges. Out of the charges to consumers for electrical service, therefore, the municipalities are paying not only all the costs of providing service and keeping the physical plant in an up-to-date and efficient condition, but in addition—by providing sums to retire the capital obligations —are steadily advancing to ownership of their undertaking free of encumbrance. With respect to the local distribution systems, many municipal "Hydro" utilities have already reached the point where their liquid assets, such as securities and investments, bank and cash balances, and accounts receivable, exceed their total liabilities.

The total investment of the municipalities in the "Hydro" undertaking—at the date of publication of this booklet—is about $380,000,000 of which $270,000,000 is invested co-operatively in power undertakings of the Hydro-Electric Power Commission and $110,000,000 in local distribution systems and other assets. The combined revenue of the Commission and of the local electric utilities exceeds $40,000,000 per annum. The total reserves of the Commission and of the municipal electric utilities for sinking fund, renewals, contingencies and insurance purposes aggregate to date more than $125,000,000.

Cost of Electrical Service in Ontario Municipalities

Visitors to Niagara frequently enquire respecting the cost of electrical service in Ontario. The accompanying diagram and table present interesting data regarding the average charges for electric light and power service. The Commission's policy and practice is to extend the benefits of electrical service to every community that can economically be reached. Notwithstanding this practice, electricity is sold to consumers of all classes at strikingly low prices.

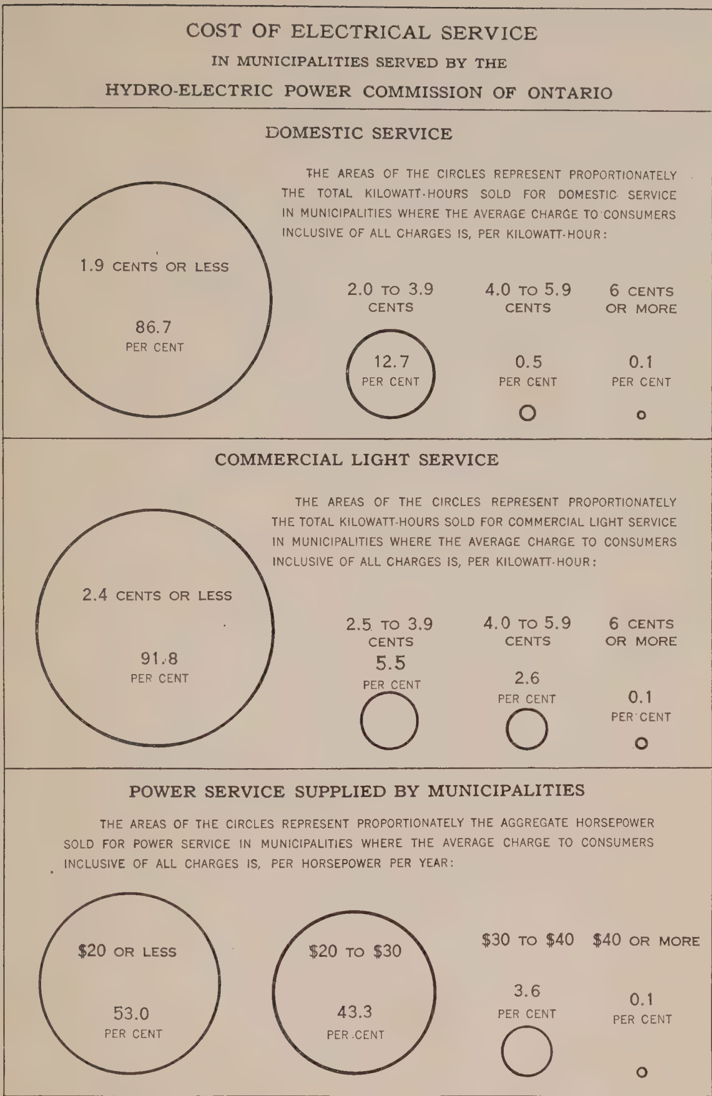
Especially in the field of domestic service has the policy of service at cost proved of benefit. The low rates resulting from this policy and the scientific rate schedules employed have induced a generous use which in turn has resulted in still lower costs. Many municipal electric utilities have been able to reduce the *distribution* costs for domestic service to less than one cent per kilowatt-hour. In more than 50 of the cities and towns served the average consumption per domestic consumer exceeds 1,000 kilowatt-hours per annum; in 11 there is an average annual consumption of 2,000 kilowatt-hours or more.

Charges for Service in Representative Ontario Municipalities

Municipality	Population	Approximate transmission distance in miles	Average net charge to consumers inclusive of all charges*		
			Residence service cents per kilowatt-hour	Commercial light service cents per kilowatt-hour	Power service dollars per horsepower per year
Toronto	606,370	78	1.5	2.3	23.70
Hamilton	144,529	53	1.4	1.3	13.78
Ottawa	125,496	1†	0.9	1.6	14.80
Windsor	70,031	238	1.6	1.8	21.00
London	69,742	123	1.4	1.5	19.97
Kitchener	30,274	95	1.7	1.7	19.15
St. Catharines	25,347	18	1.3	1.5	14.80
Peterborough	22,487	2†	1.8	1.9	18.21
Port Arthur	20,092	73†	1.2	1.5	17.92
Niagara Falls	18,539	1	1.2	1.2	17.11
Chatham	16,441	193	2.1	1.9	19.39
Owen Sound	12,778	32†	1.8	1.7	16.34
Woodstock	10,898	94	1.6	1.6	15.72
Brockville	9,432	62†	1.9	1.6	21.70
Barrie	7,166	48†	1.3	1.7	17.83
Dundas	5,137	52	1.7	2.2	15.22
Paris	4,205	76	1.8	2.1	16.73
Picton	3,146	33†	2.1	2.3	16.91
Aylmer	1,996	145	2.3	2.2	18.68
Waterford	1,091	94	1.6	1.7	18.23

*It should specially be noted that although the cost per kilowatt-hour and per horsepower affords a general measure of the economy of service to 'Hydro' consumers, these statistics are valueless as a means of comparing rates in one municipality with those in another. In researches respecting rates to consumers, the actual rate schedules in use should be employed and full account should be taken, respectively, of the influence upon costs of such factors as the distance from the source of power, the features of the power development from which service is received, the sizes and concentrations of adjacent markets for electricity, and the sizes and character of the loads supplied by the local electrical utility to the ultimate consumers. Actual bills rendered for similar service under closely comparable circumstances constitute the best basis for effecting comparisons.

†Power supply from smaller generating stations not on the Niagara river.



Note: The above diagram shows that of the total kilowatt-hours sold for domestic service, 86.7 per cent was sold in municipalities where the average charge to consumers inclusive of all charges is less than two cents per kilowatt-hour; and that similarly low costs prevail for other classes of service.

A Few Facts Respecting Water Power and Its Development

The following brief notes will, it is hoped, convey to the non-technical yet interested visitor to the great power plants at Niagara, an understanding of the principles practically applied in utilizing the flow of water to produce electricity. They will also answer many of the questions frequently asked.

The amount of *power* that can be produced depends upon two things; the *flow*, or quantity of water passing, and the *head* available, that is, the vertical distance the water can be made to fall.

The flow is usually expressed in cubic feet per second, sometimes called "second feet." The head is expressed in feet and may be entirely a natural head as in the case of a waterfall, or an artificially created head as in the case of a dam constructed across a waterway to raise its surface elevation; or it may be obtained by combining both natural and artificial heads.

The theoretical power is directly proportionate to the product of the two factors, flow and head. That is to say, with a given head, double the flow will produce double the power; or conversely, with a given flow, double the head will produce double the power.

The approximate number of horsepower available can be determined for large high-head plants by multiplying the flow expressed in cubic feet per second by the head in feet and dividing by ten. This assumes an efficiency of nearly 90 per cent. For smaller developments, where it is not ordinarily economical to attempt to attain too high an efficiency, the factor for division is usually taken as eleven, which represents an efficiency of 80 per cent.

A hydro-electric generating unit consists essentially of a hydraulic turbine to convert the potential energy of the water to mechanical energy, and an electrical generator to convert the mechanical energy to electrical energy.

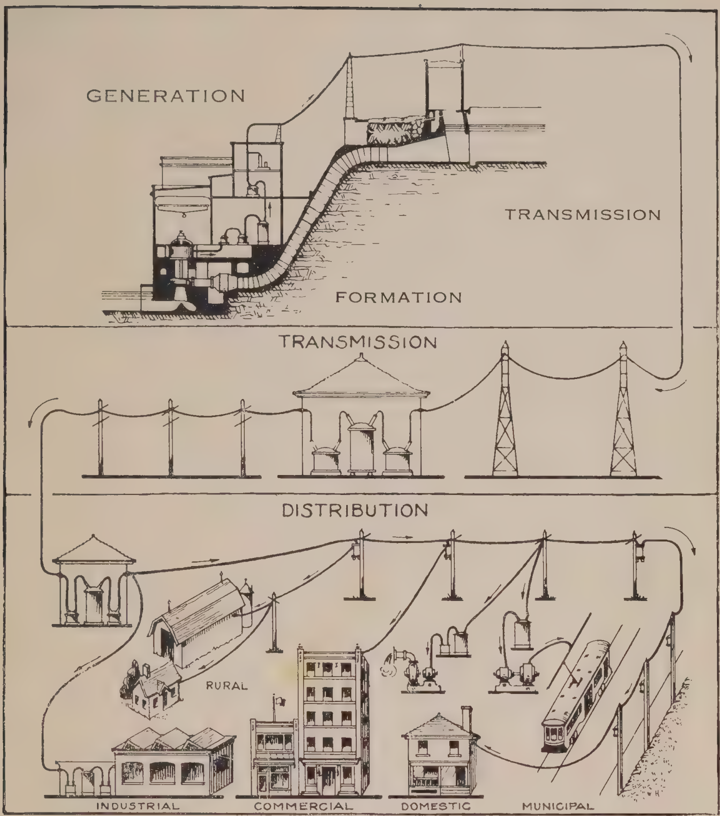
The mechanical power is produced by passing water under pressure—the "head"—through a *turbine*. The water, which should be abstracted from the river or lake at the highest elevation economically possible, is conveyed to the turbine through *canals*, *tunnels*, *pipes* or other passages or some combination of these. Arriving at the turbine, it is guided to the rotating part of the turbine—*the runner*—by a number of passages, the entrances to which can be made larger or smaller by *gates* which are opened and closed by a mechanism operated by a *governor*. After giving up its energy to the turbine runner, the water passes down the *draft tube* to the *tailrace*, whence it is allowed to escape at the lower water level.

The portion of the pipe that leads the water to the turbine is known as the *penstock*. Before the water passes to the penstock it goes through *racks* or *screens* to remove debris and also through some form of *gate* or *valve*, sometimes both.

The draft tube is a very important part of the hydraulic plant. It receives the water after it passes through the runner and is designed to discharge the water to the tail-race with the least possible energy left in the water.

The turbines are sometimes arranged with the shaft horizontal, as in the Ontario Power plant, and sometimes vertical, as in the Queenston-Chippawa plant. In either case, the shaft of the turbine projects out of the turbine case and to it is coupled the shaft carrying the revolving part of the electric generator.

Generators consist essentially of a revolving part and a stationary part, and are of two main classes, supplying either *direct current* or *alternating current*. An electric current is produced in a closed electrical *circuit* when a portion of that circuit moves in a *magnetic field*. The same effect is produced if the magnetic field moves with respect to the portion of an electrical circuit. In the *alternating current generators* of the Niagara plants the magnetic fields revolve, the revolving portion of the generator being known as the *rotor*. The stationary portion of the



generator, known as the *stator*, contains, in the form of "windings", portions of the closed electrical circuit in which it is desired to produce current. The rotor is essentially a series of powerful electric magnets arranged in a circle about an axis and these revolving magnets are energized by direct-current electricity, generated by a relatively small direct-current electric generator known as the *exciter*.

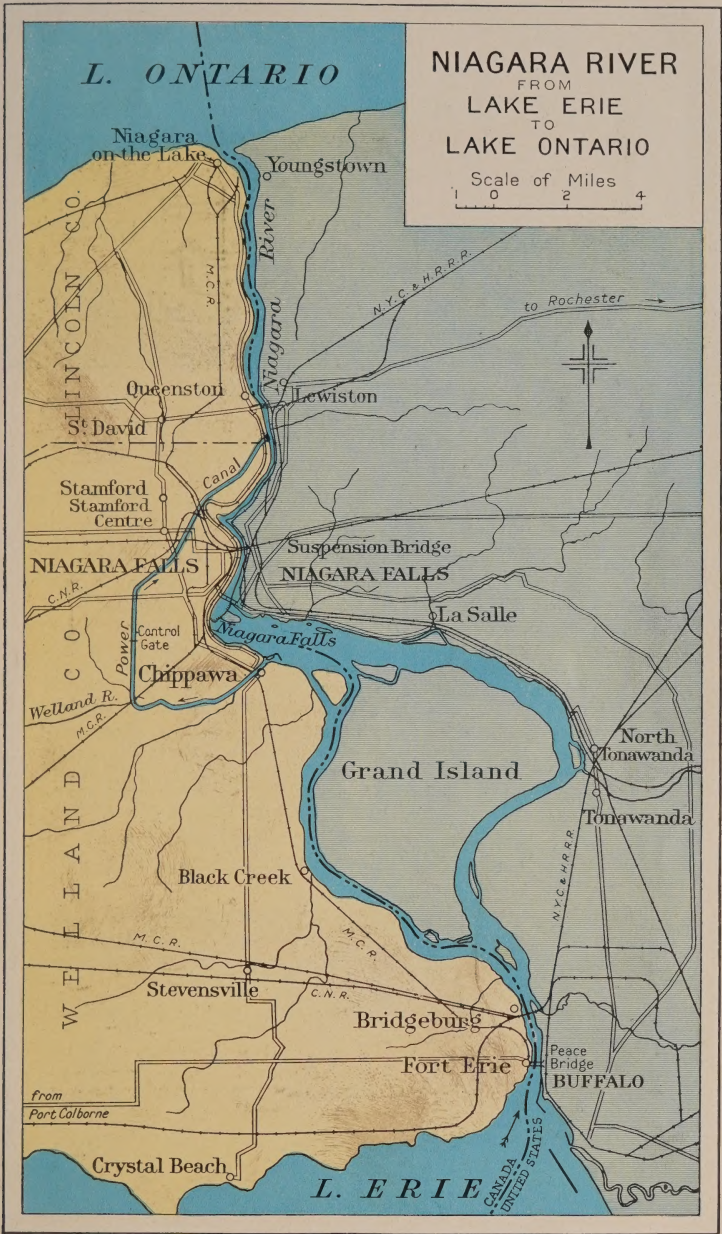
Long distance transmission of electricity is most economically carried out at high voltages. To obtain these high voltages at the Niagara power plants the electricity produced by the generators is passed through *transformers* which transform or "step-up" the voltage from 12,000 volts to 110,000 volts for transmission to the main transformer stations of the Niagara system. Since this high voltage is not necessary or suitable for shorter transmission and for moderate quantities of electricity the voltage is "stepped-down" by similar transformers to a lower voltage—26,400, 13,200, 12,000, etc., as the case may be, for transmission to distributing or municipal stations. Here it is again stepped down to 4,400 or 2,200 volts for transmission throughout a municipality or district, and finally, by the familiar transformers placed here and there on the poles on the streets, is reduced in voltage to 550, 220, or 110 volts—as the case may be—for use in the premises of consumers.

ENTRANCE GATES TO QUEEN VICTORIA PARK

Niagara Falls Park—Canada

The power plants of Ontario's great electrical undertaking which have been briefly described in the foregoing pages, are largely situated on lands administered by the Queen Victoria Niagara Falls Park Commission, an organization created in 1885 by special Act of the Ontario Legislature. The activities of this Commission have continuously been directed to the careful preservation and intelligent enhancement of the unique scenic beauties of the territory contiguous to the Niagara Falls and River. The Commission has developed a chain of splendid parks extending along the entire river front and linked together by means of an excellent boulevard 35 miles in length. Easy and free access has been made to all points of interest, and everywhere fine gardens exist. At convenient points are to be found excellent restaurants under Park control. The original Queen Victoria Park contained 154 acres, but the present Park system embraces an area of 1,500 acres, and represents in lands, buildings and equipment, a capital outlay of $3,000,000.

The Parks system, extending from lake Erie to lake Ontario is adjacent to, or includes, the following points of interest. *From lake Erie to the Falls:* The ruins of old Fort Erie; the new Peace Bridge, connecting Fort Erie with Buffalo; Navy Island and Grand Island which divide the Niagara river into two channels; Chippawa, at the mouth of the Welland river, the scene of an important engagement in the struggle of 1812-14; the intake to the Queenston-Chippawa power development and the Ontario Power development headworks. *At the Falls:* The various hydro-electric power houses, to which inspection trips may be made under competent guidance; Table Rock house; the various buildings in the Park and the superior Park Gardens. *Along the Niagara Gorge:* The Canadian city of Niagara Falls; the Whirlpool; the Aerial Railway; Niagara Glen; the great Queenston Power House; Brock's Monument and Queenston Heights Park. *Along the lower river after descending the escarpment:* The village of Queenston, and historic Niagara-on-the-Lake.


NIAGARA RIVER
FROM
LAKE ERIE
TO
LAKE ONTARIO
Scale of Miles
1 0 2 4
L. ONTARIO
Niagara on-the-Lake
Youngstown
Niagara River
N.Y.C. & H.R.R.R.
to Rochester
M.C.R.
LINCOLN CO.
Queenston
Lewiston
St David
Canal
Stamford
Stamford Centre
Suspension Bridge
NIAGARA FALLS
NIAGARA FALLS
C.N.R.
La Salle
Niagara Falls
Control Gate
Power
Chippawa
Welland R.
M.C.R.
WELLAND CO.
Grand Island
North Tonawanda
Tonawanda
N.Y.C. & H.R.R.R.
Black Creek
M.C.R.
M.C.R.
Stevensville
C.N.R.
Bridgeburg
Fort Erie
Peace Bridge
BUFFALO
from
Port Colborne
Crystal Beach
L. ERIE
CANADA
UNITED STATES

CANADIAN FALLS ILLUMINATED

Illumination of the Falls

ONE of the more recent spectacular features provided for the enjoyment of visitors to Niagara is the installation of batteries of searchlights which, from time to time—especially during the summer evenings—are focussed on both the Canadian and American Falls, brilliantly flooding them with an ever-changing variety of color.

The installation consists of twenty-four 36-inch searchlights placed on one of the buildings of the Ontario Power plant. The total candle power of this installation is 1,320,000,000, requiring some 450 horsepower. This power is supplied free by the Hydro-Electric Power Commission of Ontario. The cost of operation is defrayed by the cities of Niagara Falls, Ontario, and Niagara Falls, New York, in conjunction with the Niagara Falls Park Commission. The spectacle is witnessed by thousands of people and has attracted to the Falls many new visitors, as well as many who from earlier visits were familiar with their daytime grandeur.

AMERICAN FALLS AT NIGHT IN WINTER